is a relation between points. If we had no fixed or relatively fixed datum points, to serve as origins, and to enable us to establish direction lines, we are assured that there would be no space. We should not be able to move if there were nothing for us to bump against. We discover a certain tree in a pathless forest which no foot had trodden before. It has rings of growth and a magnitude which indicate that it must have had a history before it ever came into the thought of man. But its existence dates from its first discovery. It was pure nothingness before.

Let us imagine some unfortunate floater to have spent his life in solitude on a raft in mid-ocean. The water is smooth, the winds are at rest and the sky is continually overcast with a uniform layer of clouds. This we are to assume will involve the conclusion that latitudes and longitudes and compass directions do not exist. The fact that there are other philosophers in Paris who have enjoyed advantages which the floater has not enjoyed must not be considered.

If some of our philosophically inclined brothers would spend a little more time in defining the sense in which they are using words, and a little less time in the futile attempt to define things, the atmosphere would seem clearer. The youthful floater would be somewhat less at sea.

FRANCIS E. NIPHER

THE SATELLITES OF MARS

TO THE EDITOR OF SCIENCE: The letter of Professor Eastman in SCIENCE, No. 695, is my only excuse for taking your valuable space. In consequence of Professor Eastman's letter to the editor of the *Transcript*, there was printed in the paper this explanation: "In the account of the work of Professor Hall presented in the *Transcript* at the time of his death, reference was made to the discovery of the satellites of Mars as 'accidental.' Although the discovery did belong to the class of the accidental because it was unpredictable, still the hastily-chosen word does not describe the conditions upon which the discovery was based. The exact term is a little difficult to catch, speculative and tentative describing in a way the methods by which the observations were carried forward to success."

This note prefaced half-a-column of extract from Professor Newcomb's "Reminiscences" on the same discovery, and together they formed an article that one would not be expected to overlook. Being no longer "live" news, the article was not published till December 21.

With reference to the companions of Procyon seen at the observatory, it was simply the current gossip of the astronomers of the time, fifteen or twenty years ago, lingering in my memory. It illustrated the splendid, sterling qualities of Professor Hall better than any other story that recurred to me during the hurried preparation of the article. It is very good of Professor Eastman to set the world right in the matter, to place the discovery of the fictitious companions where it belongs and to assure us that this bit of gossip has, what most gossip lacks, a foundation.

JOHN RITCHIE, JR.

SPECIAL ARTICLES

COINCIDENT EVOLUTION THROUGH RECTIGRADATIONS AND FLUCTUATIONS (THIRD PAPER[1])

I PUBLISHED recently the statement of a law which I believe to be fundamental in the evolution of organisms, namely, "The Law of the Four Inseparable Factors."[1] It is expressed as follows:

The life and evolution of organisms continuously center around the processes which we term heredity, ontogeny, environment and selection; these have been inseparable and interacting from the beginning; a change introduced or initiated through any one of these factors causes a change in all.

[1] "Evolution as it Appears to the Paleontologist," SCIENCE, N. S., Vol. XXVI., No. 674, November 29, 1907, pp. 744–749. (First paper.)

"The Four Inseparable Factors of Evolution: Theory of their Distinct and Combined Action in the Transformation of the Titanotheres, an Extinct Family of Hoofed Animals in the Order Perissodactyla," SCIENCE, N. S., Vol. XXVII., No. 682, January 24, 1908, pp. 148–150. (Second paper.)

I have added two corollaries from my studies on the titanotheres, in which it appears to be highly probable that in different parts of the body of highly complex vertebrated animals, different evolution factors may be operating coincidently to produce a coordinated adaptive result, namely:

First, that while inseparable from the others, each process may in certain conditions become an initiative or leading factor; second, that in complex organisms one factor may be initiative in one group of characters while another factor may at the same time be initiative in another group of characters, the inseparable action bringing about a continuously harmonious result.

In a recent paper before the Zoological Society at New Haven these corollaries were illustrated in the evolution of the titanotheres, as shown in the accompanying Figs. 1, 2 and 3.

1. Selection of Fluctuations

It is observed that in four or five contemporaneous phyla of Middle Eocene titanotheres, unquestionably derived from a common lower Eocene ancestor, there is a tendency to diverge into *brachycephalic* forms (Fig. 1, *A, Palæosyops*) and *dolichocephalic* forms (Fig. 1, *C, Dolichorhinus*); the former become increasingly brachycephalic, the latter become increasingly dolichocephalic. This change of proportion is brought about as follows: (1) there is a redistribution of materials, (2) this effects a change in the entire proportions of the skull, (3) the different component bones are affected differently, because there are *distinct percentages of increment,* in breadth or in length, in the bones of each region.

First Experiment, Redistribution (Fig. 1). This proves that a general redistribution of materials will convert a brachycephalic into a dolichocephalic type. I outline the broad skull of *Palæosyops* on a sheet of India rubber and stretching the sheet lengthwise, produce the Fig 1, *B,* thus artificially creating a skull of dolichocephalic type which approximately resembles Fig. 1, *C.* This experiment illustrates what may be done by a mere redistribution of materials.

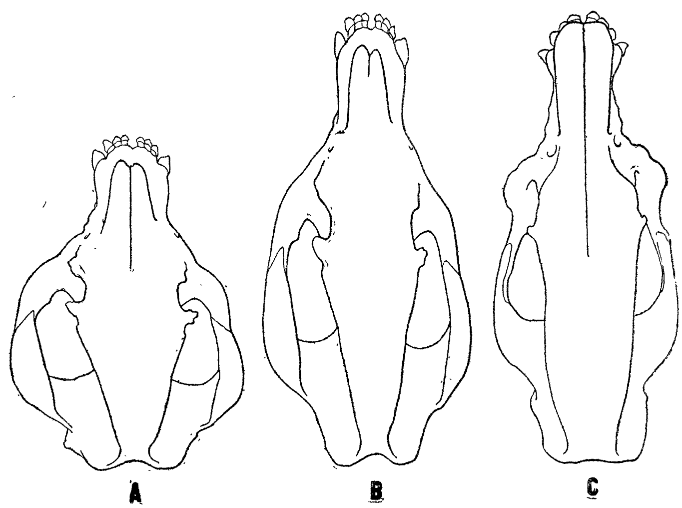

Fig. 1. Artificial Dolichocephaly.
A, Palæosyops, extreme brachycephalic type.
B, outline produced artificially by stretching *A* to length of *C.*
C, extreme dolichocephalic type, *Dolichorhinus.*

Second Experiment, Redistribution (Fig. 2). This illustrates progressive dolichocephaly. Here are represented the outlines derived by stretching and slightly expanding the skull of

a dolichocephalic animal into that of its still more long-skulled descendant. Fig. 2, *A*, represents the palatal view of a skull which is ancestral to the second skull represented in Fig. 2, *C*. An outline of the skull represented

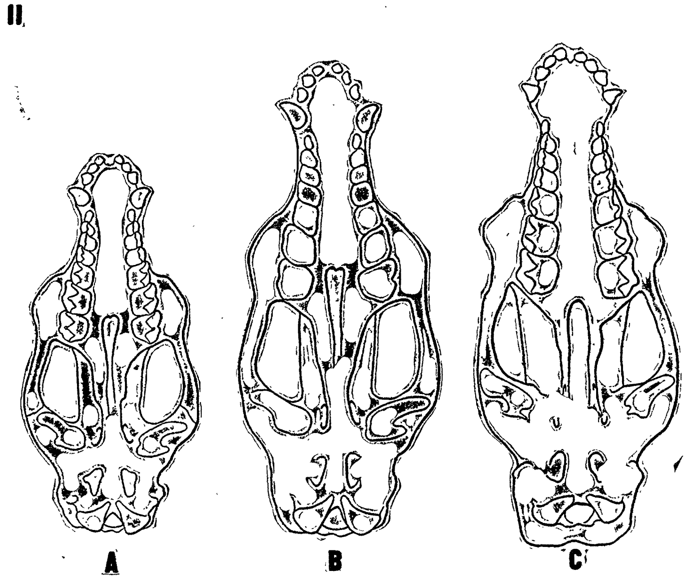

FIG. 2. Artificial Dolichocephaly.
A, a skull ancestral to *C*.
B, outline produced artificially by stretching *A* to length and width of *C*.
C, extreme long-skulled type, *Dolichorhinus*.

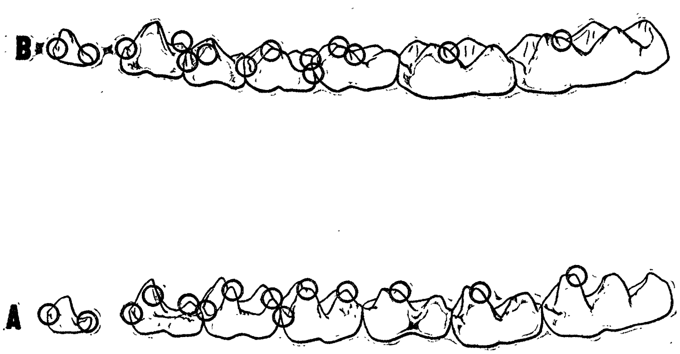

FIG. 3. Rectigradations. *A*, *Orchippus*, Middle Eocene horse; *B*, *Palæosyops*, Middle Eocene titanothere. The circles indicate new cuspules rising independently in these two phyla.

in Fig. 1, *A*, is traced on India rubber and stretched into the outline represented in Fig. 2, *B*, which it is seen gives us an approximate approach to Fig. 3, *C*.

The above two experiments prove that transition from brachycephaly to dolichocephaly or from dolichocephaly to an intensified dolichocephaly may be interpreted partly as a mere redistribution of materials, all parts being stretched in the same proportion. *But this does not describe all that actually occurs in nature, because in skull lengthening or shortening each bone is affected somewhat differently.*

I am inclined to regard dolichocephaly and brachycephaly in the vertebrates generally as caused by the natural selection of fluctuations

in a broad-skulled or long-skulled direction, respectively.

The important point to note is that the descendants of a single ancestral titanothere or of any other vertebrate may become either brachycephalic, mesaticephalic or dolichocephalic; in other words, *the primitive mesaticephalic ancestral form of skull does not control the form of skull which may be derived from it, yet an evolution tendency once established is pursued to its limits.*

2. *Tooth Evolution through Rectigradations or Orthogenesis*

Here, in contrast to the foregoing cases of brachycephaly and dolichocephaly a law of hereditary ancestral control appears to be in operation. The diagrams in Fig. 3, *A, B,* represent the origin of cuspules in two independent families of Perissodactyla which also have sprung from a very remote common ancestor.

The types selected are (*A*) *Orohippus,* a Middle Eocene horse, and (*B*) *Palæosyops,* a Middle Eocene titanothere. The teeth represent the seven grinders of the lower jaw viewed from the internal aspect. Circles surround the new cuspules, which are appearing on the inner sides of these teeth. We observe that cusp for cusp exactly the same cuspules are arising in the jaw of *Orohippus* as in the jaw of *Palæosyops,* but that, although an animal of the same geological age, *Orohippus* is acquiring its new cusps a little more rapidly than *Palæosyops,* as shown in the following table:

	Palæosyops No. of Cuspules	Orohippus No. of Cuspules
First premolar	2	2
Second premolar	2	3
Third premolar	3	4
Fourth premolar	4	4
First molar	3	3
Second molar	1	1
Third molar	1	1
Total	16	18

This comparison proves that while there is apparently a law of ancestral or hereditary control operating in the genesis of these new cusps, and that while the new cusps are orthogenetic and hence may be termed "rectigradations" (because developing in fixed lines) *such law of ancestral control does not determine the rate of evolution of the cusps in these two types.* The *rate* of evolution is more rapid in *Orohippus* than in *Palæosyops.*

This observation appears to bar the hypothesis that the appearance of these cusps is due to an internal perfecting tendency which operates independently of external conditions and to favor the hypothesis that in some unknown manner external conditions control the rate of evolution, again illustrating the law of the four inseparable factors.

Conclusion

The contrast between the origin of changes of proportion illustrated in brachycephaly and dolichocephaly and the origin of new cuspules is, apparently, that the former is independent of hereditary control and not predetermined, while the latter is predetermined or under hereditary control. Both phenomena are controlled alike as to *rate of evolution* by adaptation to external conditions, namely, by the kind of food on which the animal subsists.

These considerations appear to me to sustain my hypothesis of the independent operation of two primary factors at least to produce an harmonious adaptive result.

HENRY F. OSBORN

THE FILLING OF EMERALD LAKE BY AN ALLUVIAL FAN

ABOUT four miles northwest of the town of Field, in British Columbia, and separated from it by Mount Burgess, lies the beautiful sheet of water known as Emerald Lake. Situated near the head of a broad glacial valley, this lake has been formed probably by the damming of the original channel by a heap of glacial débris, perhaps supported by a resistant outstanding ledge of bed rock at this place. Across this barrier the water has its exit.

The present interest in Emerald Lake, however, rests not so much upon its mode of formation as upon the fact that it is slowly being